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RESEARCH DEPARTMENT

REPORT

U.H.F. relay station aerials:

the compensation of a 914 mm diameter aerial cylinder by means of an inductive grating

No. 1971/33

Research Department, Engineering Division
THE BRITISH BROADCASTING CORPORATION

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Summary

When an aerial is mounted inside a dielectric cylinder, it is possible for reflections within the cylinder to affect the impedance and radiation pattern of the aerial.

Theoretical and practical aspects of the use of inductive gratings at the surface of such a cylinder are presented in this report, together with the results of measurements conducted on aerials in cylinders equipped with gratings, showing that a useful degree of compensation of the effects of the cylinder is practicable.

1. Introduction

Many of the u.h.f. television relay stations built to date employ the standard BBC cardioid transmitting aerial.[1] This aerial consists of 16 vertically-polarised half-wave dipoles stacked vertically at intervals of one wavelength. The usual mounting arrangement consists of a 45·7 m high self-supporting tower with the aerial at the top enclosed in a 387 mm diameter vertically mounted glass-fibre cylinder, which acts both as a mechanical support and weathershield. Inspection and servicing of the aerial necessitates its removal from the cylinder and a pulley arrangement is provided for the purpose. Larger cylinders are in use at main stations, and inspection of aerials is possible from within the weathershield. The use of an intermediate size of cylinder at relay stations would provide this inspection facility but it has been shown that a cylinder with a diameter greater than one wavelength may have a severe effect upon the radiation pattern and impedance of the aerial contained within it.[2]

One solution is to use a double- or triple-walled cylinder arranged so that reflections tend to cancel,[3] but this is costly. An alternative method is to tune out effectively the capacitive reactance of the cylinder by means of an inductive grid of wires. The practical application of this method is considered in this report.

2. Theoretical considerations

2.1. The inductance of a grating composed of straight wires or helices

The effect of a dielectric sheet on an electromagnetic wave may be expressed as a surface admittance given by the formula:

$$Y_s = \frac{j}{60\lambda}(\epsilon_r - 1)W \qquad (1)$$

where Y_s is surface admittance in Siemens,
W is thickness of sheet in metres,
λ is free-space wavelength in metres,
and ϵ_r is relative permittivity of the sheet;

provided that $\frac{2\pi W\sqrt{\epsilon_r}}{\lambda}$ is small (i.e. the sheet must be considerably less than one wavelength thick).

The susceptance obtained is capacitive, and may be tuned by an inductive grating of conductors parallel to the electric field vector and close to (or embedded within) the sheet. The effect of a grating composed of closely-spaced straight wires may be expressed as an inductive surface admittance given by the formula:

$$1/Y_g = j\frac{120\pi d}{\lambda}\log_e(d/2\pi r) \qquad (2)$$

where Y_g is surface admittance in Siemens,
d is spacing between the axes of adjacent wires,
λ is the wavelength,
r is the radius of each wire,
(in metres)

This formula can be applied when r/d is small and $d<\lambda/4$.

Formulae (1) and (2) may be used to estimate the dimensions of an ideal grating to compensate for the surface admittance of a dielectric sheet. The cylinder used for the measurements described in this report had a wall thickness of 9 mm, and was made from glass-fibre material having a relative permittivity of approximately 4·5. The ideal grating for compensating such a cylinder requires wires of about 0·001 mm diameter, closely spaced; they would thus be so fine as to be incapable of carrying the induced currents and would also be mechanically very fragile.

It is, however, possible to use straight wires of reasonable thickness by increasing the spacing to 0·4 wavelength. The spacing is then outside the limits given for Equation (2) so that the grating can no longer be regarded as continuous. Nevertheless the impedance compensation afforded by the more widely spaced grating is just as effective, and it gives acceptable radiation patterns. Straight wire elements of diameter 0·31 mm (30 s.w.g. wire) would be suitable and although wire of this size is satisfactory from constructional considerations, the possibility of damage by lightning stroke has to be borne in mind. To increase the thickness of the wire and still obtain proper compensation it has been proposed[4] that the grating wires should be coiled into helices of suitable pitch and diameter. In practice if helices are used then the wire thickness may be increased to about 20 s.w.g. However, estimates show that the likelihood of lightning strikes of an intensity to fuse even the finer wire is very small and it is probable that the straight-wire grating would be quite satisfactory in practice.

2.2. An estimate of the current induced in the wires of a grating surrounding an aerial

An estimate of the current induced in the wires by the radiating dipole elements can be made from the inductive surface admittance of the grating by calculating the field from the dipoles at the wires. A cross-sectional diagram of a cylinder equipped with a grating is shown in Fig. 1. The surface current is distributed between the wires according to their distance from the dipole axis.

A Type A relay station radiates 625 W mean vision power and 200 W mean sound power per channel. For a total of four programmes therefore the mean power will be 3·3 kW. This means that the total current through the inductive grating will be approximately 3·5 amps (r.m.s.). With the dipoles at a distance (a) of 150 mm from the cylinder wall, and with a grating of 20 wires the current in the wire closest to the dipoles is found to be 0·576 amps (r.m.s.), with correspondingly lower currents in the wires more remote from the dipoles. This is well within the rating of 30 s.w.g. wire which has a fusing current of about 15 amps in air.

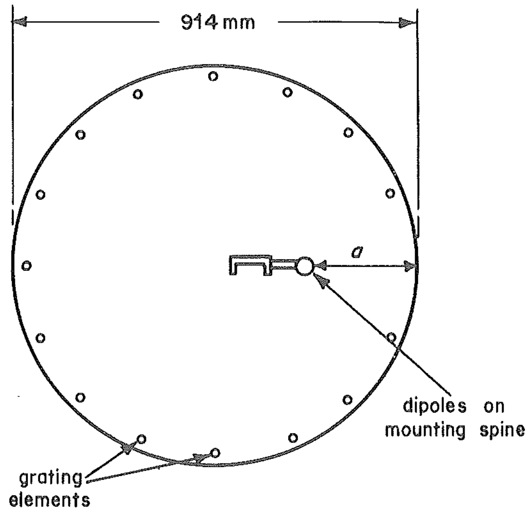

Fig. 1 - Cross-sectional view of cylinder

TABLE 1

Grating Details

Grating No.	Type of element	Spacing between elements	Dipole-cylinder wall spacing
1.	Straight-wire	240 mm	191 mm
2.	Helical	140 mm	152 mm
3.	Straight-wire	172 mm	197 mm
4.	Helical	114 mm	197 mm
5.	Straight-wire	150 mm	152 mm
6.	Helical	97 mm	152 mm

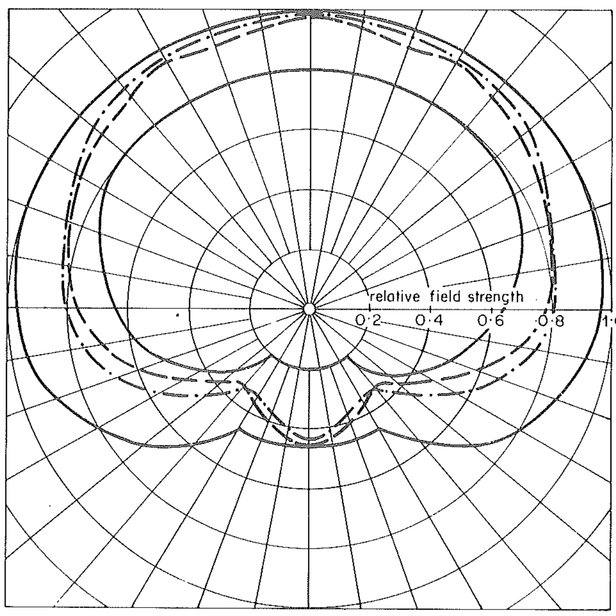

Fig. 2 - Horizontal radiation patterns of Band IV aerial in 914 mm diameter cylinder with straight-wire grating (grating 1 in Table 1)

— — — — 500 MHz — · — · — 600 MHz
———— Limits of pattern set by templet

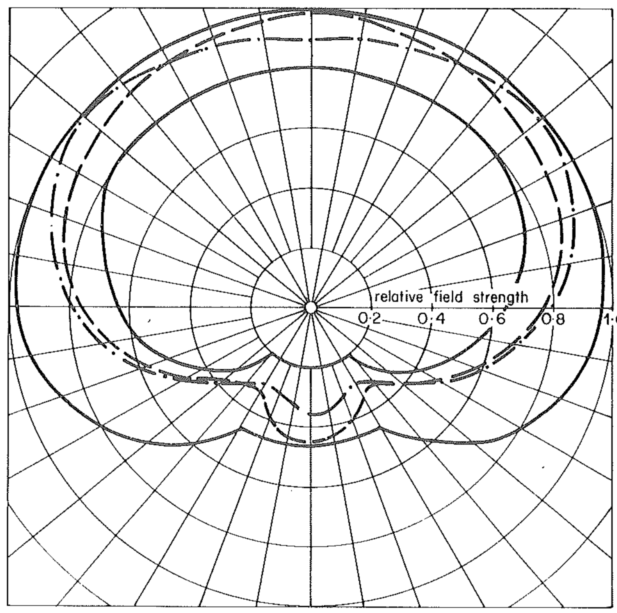

Fig. 3 - Horizontal radiation patterns of Band IV aerial in 914 mm diameter cylinder with helical-wire grating (grating 2 in Table 1)

— — — — 500 MHz — · — · — 600 MHz
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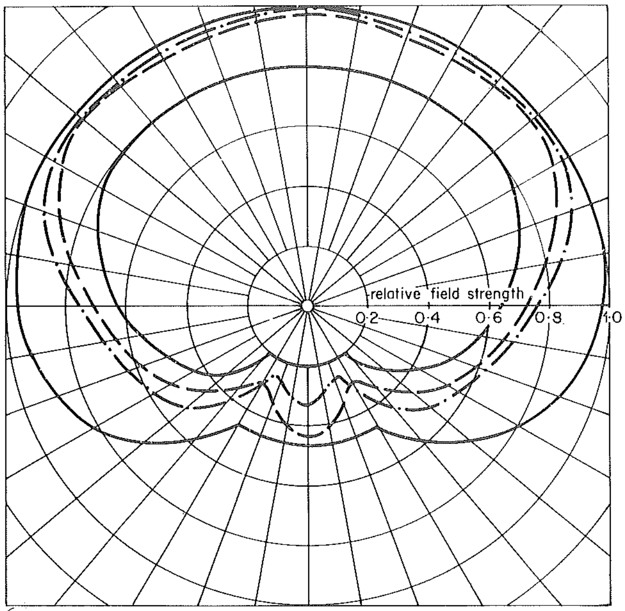

Fig. 4 - Horizontal radiation patterns of lower Band V aerial in 914 mm diameter cylinder with straight-wire grating (grating 3 in Table 1)

600 MHz   700 MHz

Limits of pattern set by templet

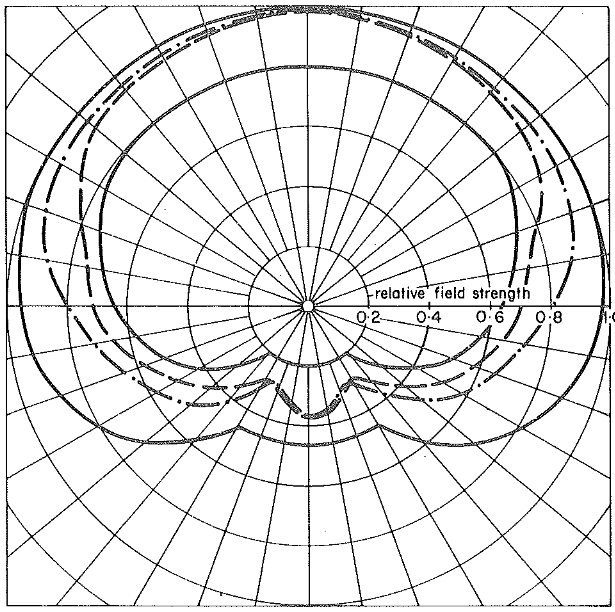

Fig. 5 - Horizontal radiation patterns of lower Band V aerial in 914 mm diameter cylinder with helical-wire grating (grating 4 in Table 1)

600 MHz   700 MHz

Limits of pattern set by templet

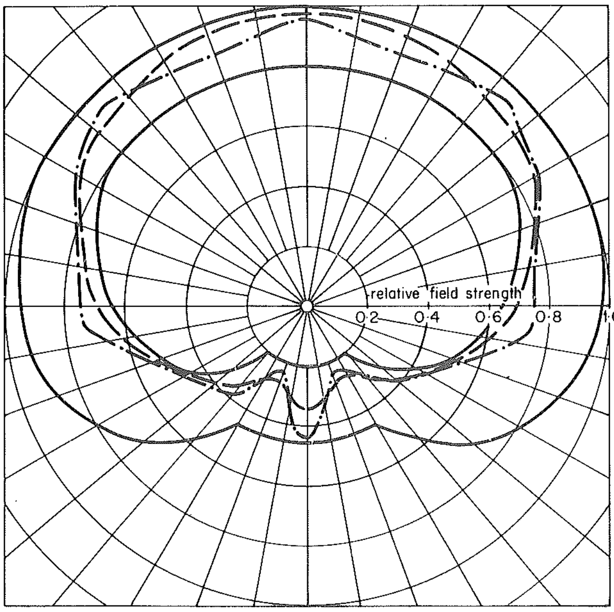

Fig. 6 - Horizontal radiation patterns of upper Band V aerial in 914 mm diameter cylinder with straight-wire grating (grating 5 in Table 1)

700 MHz   850 MHz

Limits of pattern set by templet

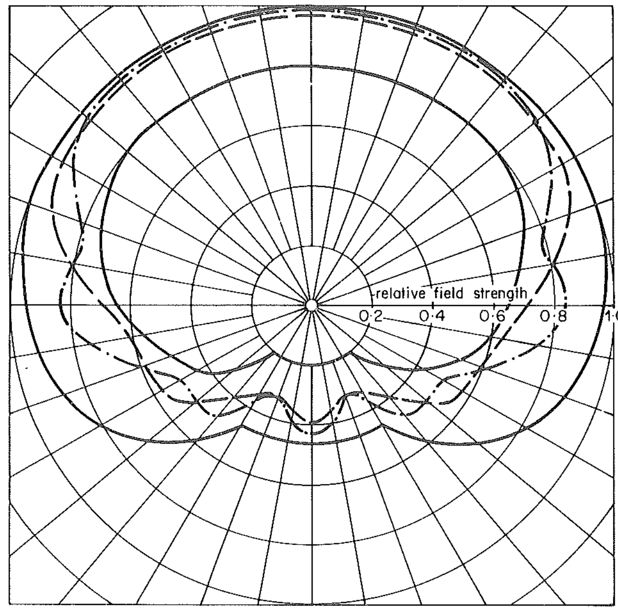

Fig. 7 - Horizontal radiation patterns of upper Band V aerial in 914 mm diameter cylinder with helical-wire grating (grating 6 in Table 1)

700 MHz   850 MHz

Limits of pattern set by templet

Straight-wire elements consist of 30 s.w.g. enamelled copper wire. Helical elements consist of 23 s.w.g. enamelled copper wire wound on 6 mm diameter insulating rods, with a pitch of 6 mm.

3. Measurements on aerials in a 914 mm diameter glass-fibre cylinder with a surface grating

3.1. Radiation pattern measurements

Horizontal radiation patterns were measured on aerials consisting of Band IV, lower and upper Band V dipoles mounted on a supporting spine in a 914 mm diameter glass-fibre cylinder. The measurements were conducted with both straight wire and helical grating elements. The dipoles were positioned towards the edge of the cylinder, most results being obtained with a dipole-wall spacing in the range 150 – 200 mm, this position being chosen to leave sufficient climbing space for access and maintenance purposes.

A selection of radiation patterns measured in Bands IV and V are shown in Figs. 2 – 7. Details of the gratings used in these measurements are given in Table 1; little

difference has been found between results obtained with gratings on the inner and outer surfaces of the cylinder.

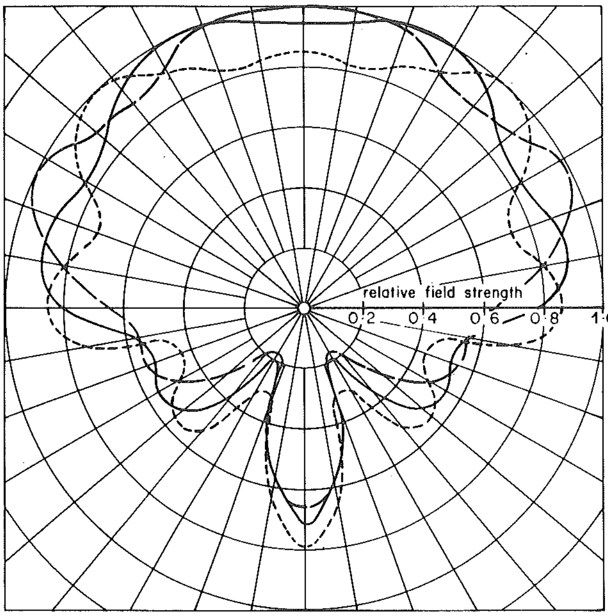

Fig. 8 - Horizontal radiation pattern of upper Band V aerial in 914 mm diameter cylinder. Dipole-wall spacing 146 mm
— — — 730 MHz ——— 790 MHz - - - - 850 MHz

The horizontal radiation pattern of a relay station aerial in a 914 mm cylinder without gratings is shown in Fig. 8; the dipole-wall spacing is 146 mm in this case. Comparison with Figs. 6 and 7 reveals the extent to which the radiation patterns have been corrected and brought within the limits defined by the templet.

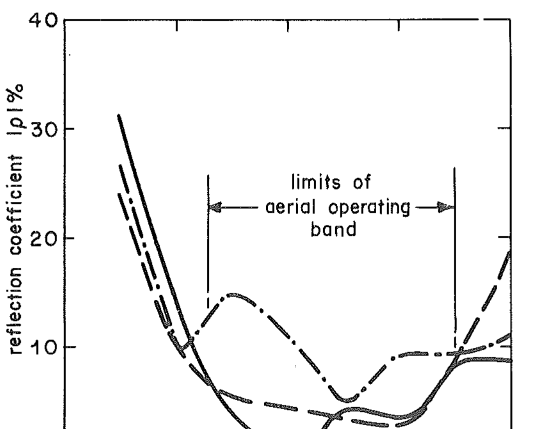

Fig. 9 - Reflection coefficient of lower Band V aerial in 914 mm diameter cylinder with straight-wire grating
— — — aerial in free space
—·—·— aerial in cylinder with no compensation
——— aerial in cylinder with straight-wire grating

3.2. Impedance measurements

The reflection coefficients of aerials for Band IV and both halves of Band V were measured with the aerials in free space and also mounted within cylinders (with and without inductive gratings). Typical results are shown in Figs. 9 and 10, and it will be seen that reasonable reflection coefficients are obtained over the operating frequency range of a lower Band V aerial using both straight-wire and helical elements in a grating. Similar results have been obtained over Band IV and upper Band V.

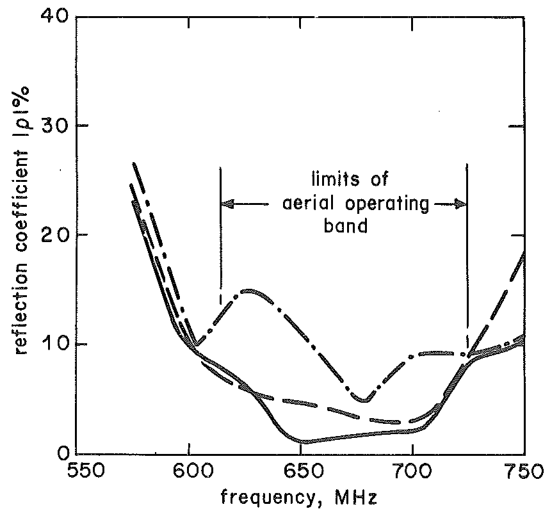

Fig. 10 - Reflection coefficient of lower Band V aerial in 914 mm diameter cylinder with helical-wire grating
— — — aerial in free space
—·—·— aerial in cylinder with no compensation
——— aerial in cylinder with helical-wire grating

Although correction of the impedance of an aerial in a cylinder by the use of a grating is not complete at all frequencies in the operating band, a considerable improvement is obtained over the results obtained when the aerial is mounted in an uncompensated cylinder.

4. Conclusions

Experiments with two types of inductive grating attached to the surfaces of a glass-fibre cylinder have demonstrated their effectiveness in compensating for the surface admittance of the cylinder. Acceptable radiation patterns and reflection coefficients have been obtained over the operating frequency range of each aerial tested with this arrangement.

It would be desirable, before equipping stations with cylinders compensated by gratings, to investigate the problem of lightning damage, preferably by conducting high-voltage tests.

5. References

1. A vertically-polarized transmitting aerial for UHF relay stations. BBC Research Department Report No. E-122, Serial No. 1966/74.

2. UHF relay station aerials inside 914 mm diameter glass-fibre cylinders. BBC Research Department Report No. RA-16, Serial No. 1968/18.

3. Multiple wall weathershields for UHF aerials. BBC Research Department Report No. 1970/33.

4. BBC Patent application No. 7597/70. Reducing electromagnetic reflection from dielectric sheets.

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